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Suitcase Lab Measurement of Digital Cellphone Interference Levels on Hearing Aids

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Abstract

A low-cost, "real-life" method for measuring the interference caused by digital wireless (cellphones) telephones in hearing aids is proposed. Data would be valid for specific telephone and hearing aid models. The estimated equipment cost is $500.

Key Words: Digital cellphone, hearing aid interference

Abbreviations: AGC = automatic gain control, ANSI = American National Standards Institute, BTE = behind the ear, CD = compact disc, CIC = completely in the canal, DLH = damped long horn, IRIL = input referred interference level, PCS = Personal Communication System, RF = radio frequency, TEM = transverse electromagnetic

At the time that this article was written (*Killion and Teder, 1999*), the C63.19 American National Standards Institute (ANSI) Task Force was converging on measurement techniques that are rigorous and precise but cost an estimated $25,000 to $50,000 in instrumentation. That standard has now been approved, and the approved method offers the most reproducible results, yet we feel that there is still a need for an alternative, more affordable procedure. An alternative method has been developed, and it is hoped that it will trigger experiments by others. It is offered for three reasons:

1. It requires equipment costing only a few hundred dollars.
2. The transverse electromagnetic (TEM) radio frequency (RF) cell used for the ANSI work cannot generate the very high field strengths that are required (up to 250 V/m) or the electric and magnetic field gradients measured under some wireless telephones at the hearing aid position. The TEM cell generates instead a uniform field free of significant gradients. The alternative method uses the specific wireless telephone of interest and therefore generates whatever actual field strength and field gradient will be encountered in practice with *that* wireless telephone.
3. The TEM cell approach assumes that the problem is caused primarily by the far-field field strength, which may not always be the case. The problem could instead be caused mostly by a near-field gradient, as pointed out by Elmer Carlson of Knowles Electronics (personal communication, 1999).

The proposed alternative method provides a safeguard against designs that look good in a TEM cell but might exhibit problems in real life. It is possible to design an RF pickup (and thus presumably a hearing aid) that is insensitive to a plane-wave field but highly sensitive to a gradient. An example is a pair of coaxial coils connected in opposition; such an arrangement would have low sensitivity to a uniform field but differential sensitivity to a gradient.

ALTERNATIVE METHOD SUMMARIZED

1. Measure the cellphone-caused buzz output of a hearing aid in a 2-cc coupler.
2. Remove the telephone and then introduce a *prerecorded acoustic buzz at the input to the* hearing aid microphone. Adjust the level of

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this acoustic buzz until the hearing aid produces the same 2-cc coupler output as it did in step 1 with the cellphone.

3. Measure the level of the acoustic buzz at the hearing aid. It is equal to the input referred interference level (IRIL) for *that* hearing aid with *that* telephone.

An advantage to this method is that hearing aids with automatic gain control (AGC), particularly wide-dynamic-range compression aids, will be forced to the same gain for the buzz generated by the RF electromagnetic field (the "RF buzz") as for the acoustic buzz using this measurement technique.

The method, however, is limited to microphones with a reasonably good low-frequency response. When a microphone with a substantial low-frequency roll-off is used, the acoustic buzz will be attenuated by the roll-off, whereas the RF buzz may have less or no roll-off. Our measurements with 6 dB/octave slope microphones indicate that these may require 27 dB greater acoustic input for a 50-Hz buzz and 15 dB greater acoustic input for a 217-Hz buzz. Fortunately, conventional hearing aid microphones have a relatively flat response down to 217 Hz, and the required corrections are manageable.

EQUIPMENT REQUIRED

The system has been tested and can be replicated by any interested party. The equipment required is as follows (Fig. 1):

1. A pair of sound level meters. The Radio Shack P/N 33-2050 ($34.99) is adequate for these tests, although precision condenser microphones and sound measurement equipment may be used. Meters are set to C weighting or "flat" response.
2. A 2-cc coupler fitting over the meter microphone. Soft plastic couplers made to fit over the Radio Shack sound level meter can be obtained from Etymotic Research ($15.00).
3. A loudspeaker driven by a compact disc (CD) player and amplifier. An inexpensive "boom box," such as Radio Shack model CD3323, contains all of the necessary elements required to generate the required sound levels. The sample tested produced 94 dB at 10 inches on the 50-Hz buzz and 100 dB at 10 inches on the 217-Hz buzz. Whereas cassette players could be used, those we tried did not have as good a frequency response as CD players.

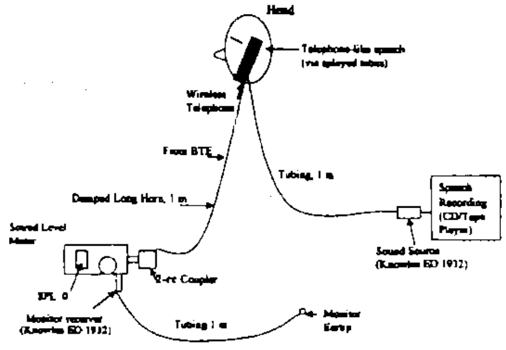

Figure 1 Measuring the level of wireless telephone hearing aid interference (SPL 0).

4. A CD containing a 50-Hz ⅓-duty-cycle buzz on one band and a 217-Hz ⅛-duty-cycle square-wave buzz on another band to provide the equivalent acoustic reference signals corresponding to U.S. time division multiple access and Personal Communication System (PCS)-1900 (Global System for Mobile) signals, respectively. Such a CD is available from Etymotic Research.
5. A cassette player with a voice tape.
6. A hearing aid receiver (Knowles ED 1932 or equivalent) connected to 1 m of #16 silicone rubber tubing terminated in a splayed set of minitubes (Fig. 2) that produce a telephone-like near-field audio signal when attached over the speaker outlet holes of the wireless telephone. This simulates the normal acoustic output of the telephone during positioning of the handset. (Using the sound directly from the tip of the #16 tubing, although simpler, can create an acoustic "hotspot.")

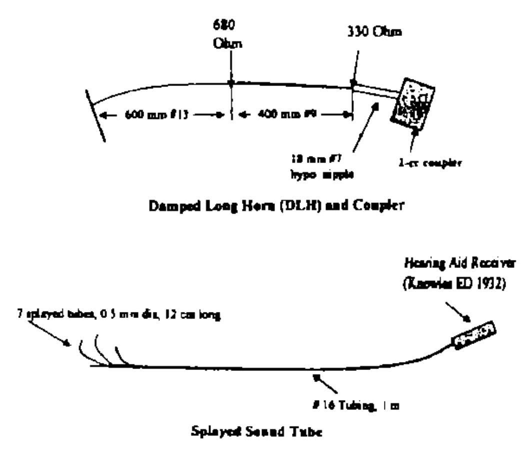

Figure 2 Damped long horn and splayed sound tube.

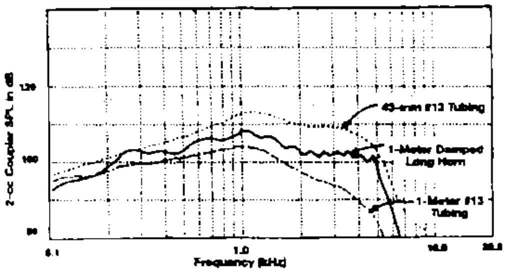

Figure 3 Frequency response of a typical BTE hearing aid with three different types of acoustic tubing.

7. A damped long horn (DLH) coupling tube (see Fig. 2) to connect the hearing aid to the coupler.
8. A commercial wireless telephone in the test mode, programmed to full power, as the RF source.

RF immunity claims would have to be limited to the specific models tested. Obtaining a complete assortment of digital wireless telephones would be much less expensive than the laboratory set-up for the ANSI standard and should produce results with good face validity.

NOTE ON THE DAMPED LONG HORN

A distance of 1 meter between the hearing aid and the 2-cc coupler will normally ensure acceptably low levels of RF interference at the test equipment. One meter of single-diameter #13 (1.93-mm internal diameter [ID]) earmold tubing introduces 15 to 20 dB of high-frequency attenuation in the band of interest. Figure 3 shows the calculated and measured frequency responses of a typical behind-the-ear (BTE) hearing aid measured with (a) the normal 43 mm of undamped #13 tubing, (b) the DLH, and (c) 1 meter of #13 tubing. The DLH substantially reduces the high-frequency loss seen with the #13 tubing.

The DLH (see Fig. 2) consists of 600 mm of #13 tubing terminated with a 680-ohm damper, followed by 400 mm of #9 (3-mm ID) tubing terminated with a 330-ohm damper placed in a short section of #13 tubing press fit into the #9 tubing, followed by an 18-mm section of #7 (3.8-mm ID) tubing terminated at the top plane of the 2-cc coupler volume. Essentially similar results are obtained with 4- and 2-mm ID tubing substituted for #9 and #13 tubing, respectively.

PROCEDURE: BTE AIDS

1. The aid (see Fig. 1) is connected to the 1-m-long DLH terminated in a 2-cc coupler on the sound level meter, which is located about 1 meter from the cellphone. The hearing aid is placed on a willing ear, and the wireless telephone is then positioned over the hearing aid. While watching the 2-cc coupler sound level meter (and monitoring its output with an earphone), the hearing aid position is adjusted to minimize the sound pressure level reading produced by the RF-induced buzz while maintaining good acoustic coupling. It is recommended that the signal reaching the sound level meter be monitored by ear, as shown in Figure 1. This provides a useful check as to whether the appropriate signals are being measured.

   Caution: As a check on the validity of the measurement, the tubing from the hearing aid should be pinched closed, whereupon the level of the buzz should drop dramatically. If it does not, then the buzz is being picked up in the sound level meter wiring and not by the hearing aid. Before switching on the hearing aid, position the sound level meter so as to avoid any buzz being picked up by the measuring system.
3. The hearing aid volume control is adjusted to produce an output reading of approximately 90 dB in the 2-cc coupler, which should ensure that the hearing aid is operating well below overload. If 90 dB SPL is not reached at full volume control setting, leave the hearing aid set at full-on gain, providing that no audible feedback occurs. If feedback occurs, reduce the gain until the monitored signal is buzz only. Record the 2-cc coupler SPL reading as SPL 0.
4. Next, remove the hearing aid from the wireless telephone and, without disturbing the volume control setting or the coupling to the 2-cc coupler, place the hearing aid over the microphone of the second sound level meter and hold the combination a few inches in front of the loudspeaker of the CD player. Using the appropriate 50- or 217-Hz buzz band on the CD, adjust the acoustic output of the loudspeaker until the 2-cc coupler SPL reads the same as SPL 0. Record the sound pressure level at the hearing aid microphone inlet (as measured on the second sound level meter) as SPL 1, which is numerically equal to the IRIL.

Although the first sound level meter is used only to obtain a reasonable undistorted output from the hearing aid, the calibration accuracy of the second sound level meter is important and should be adjusted to provide a reading of 94 (± 0.5) dB for a 1-kHz 94 dB SPL calibration tone (such as produced by a typical microphone calibrator). The Radio Shack sound level meter on the 60-dB scale can be read just to the 55-dB maximum IRIL allowed for a PCS-1900 217-Hz buzz. A Type II sound level meter with a more sensitive scale should be used if one is available, allowing reporting of IRILs of 40 or 45 dB (which can be achieved in some hearing aid designs) rather than simply reporting that it meets the 55-dB requirement.

Caution: We have found that a sound-proofed booth is required to make accurate measurements to below 50 dB SPL on the C scale. The rumble of air conditioning and passing traffic can often reach those levels even in an ostensibly quiet room with the doors closed.

PROCEDURE: IN-THE-EAR, IN-THE-CANAL, AND COMPLETELY-IN-THE-CANAL AIDS

The procedure is the same as for BTE aids, except that the eartip is coupled to the DLH with an adapter nipple such as is used with listening stethoscopes, and the hearing aid should be held in the opening formed by a nearly closed hand when measuring the RF-induced buzz. The hand is used to simulate the RF absorption of the ear and head. As before, the splayed tube providing the simulated acoustic telephone source (described above) is positioned on the hand next to the hearing aid microphone. The wireless telephone should be positioned for maximum acoustic pick-up and minimum RF-induced buzz using the monitored output of the hearing aid as the guide.

DISCUSSION

1. Applying this method to handheld in-the-ear, in-the-canal, and completely-in-the-canal (CIC) hearing aids assumes that the cupped hand around the hearing aid will reduce the RF-induced buzz to levels similar to the effect of the ear and ear canal. Richard Brander at Beltone (personal communication, 1999) has reported probe-microphone experiments with a CIC hearing aid where the in situ interference level was greater than that obtained when the hearing aid was held in free space in exactly the same position relative to the wireless telephone. This suggests that a shielded probe-tube microphone may be required to measure the output of the hearing aid in situ in some cases.
2. The above technique does not depend on whether the hearing aid is linear or has an AGC circuit. An AGC circuit could produce false measurements using the traditional method where the measured acoustic gain of the hearing aid is subtracted from the level of the RF-induced buzz. The acoustic gain and the level of the buzz at the output both depend on the input level. By fixing the output, any AGC action should affect both measurements equally. Similarly, using the same type of buzz for both measurements reduces the dependence on the frequency response characteristics of the AGC detector circuit.
3. The required IRIL has not yet been unequivocally determined but appears to be one that gives a signal-to-noise ratio of 20 dB for a 50-Hz buzz and 25 dB for a 217-Hz buzz.
4. Probe measurements by the second author indicate that the sound pressure level with the telephone over the BTE microphone inlet will be 10 dB less than that measured when the earphone is held against the ear. Thus, the cellphone standard full-volume 97 dB SPL output becomes 87 dB. Depending on how much margin for error we allow, we could argue for either 85 or 80 dB SPL as the assumed acoustic signal level. Taking the latter number gives an IRIL maximum of 60 dB (80 – 20) for a 217-Hz buzz and 55 dB (80 – 25) for a 50-Hz buzz.

If we could verify on a variety of BTE hearing aids and wireless telephones that the hearing aid microphone will consistently see 85 dB, these allowable IRIL numbers would increase by 5 dB.

Note that some, if not all, commercial digital wireless telephones start out at full power. Thus, calling a known telephone number that does not answer will result in a few seconds where the buzz level is maximum. This will allow for a check on the adequacy of the position for acoustic coupling. If all digital wireless telephones function in this way, then no more than a few working telephones are needed to check for levels in a given service area. Checking 1900-MHz operation outside a PCS-1900 service area would require digital wireless telephones with a special test mode.

It would be most helpful if wireless telephone manufacturers would add a 500-Hz or 1-kHz acoustic test tone to the wireless telephone output in the test mode. This would simplify positioning the wireless telephones over the hearing aid for maximum sound output and minimum RF-induced buzz.

Since the spectrum of speech and that of speech spectrum noise differ from the spectrum of the RF-induced buzz—especially in the case of the 50-Hz buzz—the IRIL as defined above is not strictly equal to the input level of an acoustic buzz having the same spectrum as speech. Moreover, the RF-induced buzz may affect AGC systems somewhat differently than the speech spectrum signals, depending on the frequency shaping in the circuits that detect the buzz. The likely error appears to be less than 5 dB in most cases, which is considered acceptable for this application. Where more accurate measurements are deemed necessary, the AGC system may be locked to a fixed gain either electrically or by the use of single-frequency locking tones (one per channel of the hearing aid), which are filtered from the output.

The telecoil is often considered a relatively noise-free input that does not pick up acoustic room noise. However, it is only as free as the sidetone circuit permits. Wireline telephones have built-in circuits and gain control to prevent unstable acoustic feedback that could result from high levels of sidetone. It is suggested here that these design considerations be revised for wireless telephones, particularly for wireless telephones used in noisy environments, because the local noise is fed to the earphone output and masks the incoming signal. Indeed, cellphone use in automobiles is often made more difficult by the noise from the sidetone circuit than any noise at the other end. Acoustic or telecoil, a side-tone reduction switch would be a boon for both normal and hearing-impaired users. A software switch could be used.

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